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SPECKLE INTERFEROMETRY AT THE US NAVAL OBSERVATORY. XIII.

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ABSTRACT

The results of 1424 speckle interferometric observations of double stars, made with the 26 inch (66 cm) refractor of the US Naval Observatory, are presented. Each speckle interferometric observation of a system represents a combination of over 2000 short-exposure images. These observations are averaged into 1053 mean relative positions and range in separation from 0.36″ to 61.92″, with a median separation of 10.31″. This is the 13th in a series of papers presenting measurements obtained with this system and covers the period 2006 January 12–December 29. Included in these data are nine older measurements whose positions were previously deemed possibly aberrant but are no longer classified this way following a confirming observation. This paper also includes the first data obtained using a new "secondary" camera, designed and built at USNO.

Key words: binaries: general — binaries: visual — techniques: interferometric

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1. INTRODUCTION

From 2006 January 12 through December 29, the 26 inch (66 cm) telescope of the US Naval Observatory was used on 76 of 249 (31%) scheduled nights. While most nights were lost due to marginal weather conditions, nights were also lost due to equipment upgrades and observing on other telescopes, plus transit time. Full descriptions of the techniques and methodology of speckle interferometry are contained in earlier papers in this series and references therein (most recently, Mason et al. 2006a).

The instrumentation used during the first 5 months of the year was the same as that described in Mason et al. (2006a). However, a new "secondary" speckle camera, designed and built by the USNO instrument shop, was installed in May, and after a short period of testing it was put into regular use for the remainder of the year.

While individual nightly totals varied substantially (from 2 to 72 objects per night), the results from both cameras together yielded 2324 observations and 1813 resolutions (i.e., usable double-star measurements). After removing marginal observations, calibration data, and tests, a total of 1424 measurements remained, which were grouped into 1053 mean positions. Included in these are 83 confirmations of binaries with only one previous observation. While some of these are relatively recent discoveries of the *Hipparcos* or Tycho missions (Perryman et al. 1997), some remained unconfirmed for over 100 years. Also included in these data are one observation from 2004 and eight from 2005. These measurements were not published in Mason et al. (2006a and 2006b, respectively), as they were significantly different from previous observations or orbital predictions; however, they have now been confirmed with new measurements obtained in 2006. Some of these discrepancies reflect the prematurity of earlier orbit calculations; indeed, one important reason for these observations is to improve on the orbital elements of binaries through long-term monitoring and correction of trends in residuals.

2. HARDWARE AND OBSERVING LISTS

The base speckle camera was most recently described in Mason et al. (2006a). For systemic redundancy and optimal observing efficiency when this camera is undergoing maintenance or at a remote observatory, the USNO instrument shop, led by one of us (G. W.), constructed a "secondary" speckle camera. This instrument (Fig. 1) utilizes a less sensitive ICCD (described in Germain et al. 1999) but contains multiple interference filters (Strömgren y and Johnson V) and microscope objectives (20, 10, and 3.5 times), mounted on two sliding spindles. As this instrument was only to be used with the 26 inch refractor, Risley prisms were not deemed necessary. Table 1 gives several parameters of comparison for the two cameras.

The "primary" camera was used from January until the end of May, a total of 24 of 75 (32%) scheduled nights. These resulted in 747 observations and 509 resolutions (i.e., usable double-star measurements). After removing marginal observations, calibration data, and tests, a total of 393 measurements remained, which were grouped into 269 mean positions.

The observing list used with this camera was constructed using the same methodology discussed in Mason et al. (2006a, 2006b) and earlier papers in the series. This list, of roughly 3100 pairs, was comprised mostly of systems brighter than $V = 11$, with separations between 0.2″ and 6.0″ and magnitude differences (Δm) less than 3. The majority of these systems are considered either "neglected" (the last date of observation being 10 or more years ago) or doubles needing confirmation. Several additional sets were added, including objects with uncertain motion, objects with definitive orbits (used to characterize errors), pairs with expected rapid motion, and bright ($V < 7$) stars used for navigation.

A new observing list was prepared for the secondary camera, which was mounted to the telescope in early June. While the secondary camera could observe some systems in common with the primary camera, it could go neither as faint nor as close. On the other hand, we were able to observe many other wide neglected pairs. The secondary camera was used for the rest of the year, 52 of 174 (30%) scheduled nights. These resulted in 1577 observations and 1304 resolutions. After removing marginal observations, etc., the 1031 remaining measurements were grouped into 784 mean positions.

3. CALIBRATION

Absolute calibration for the primary camera is determined by the use of a slit mask placed at the objective end of the telescope

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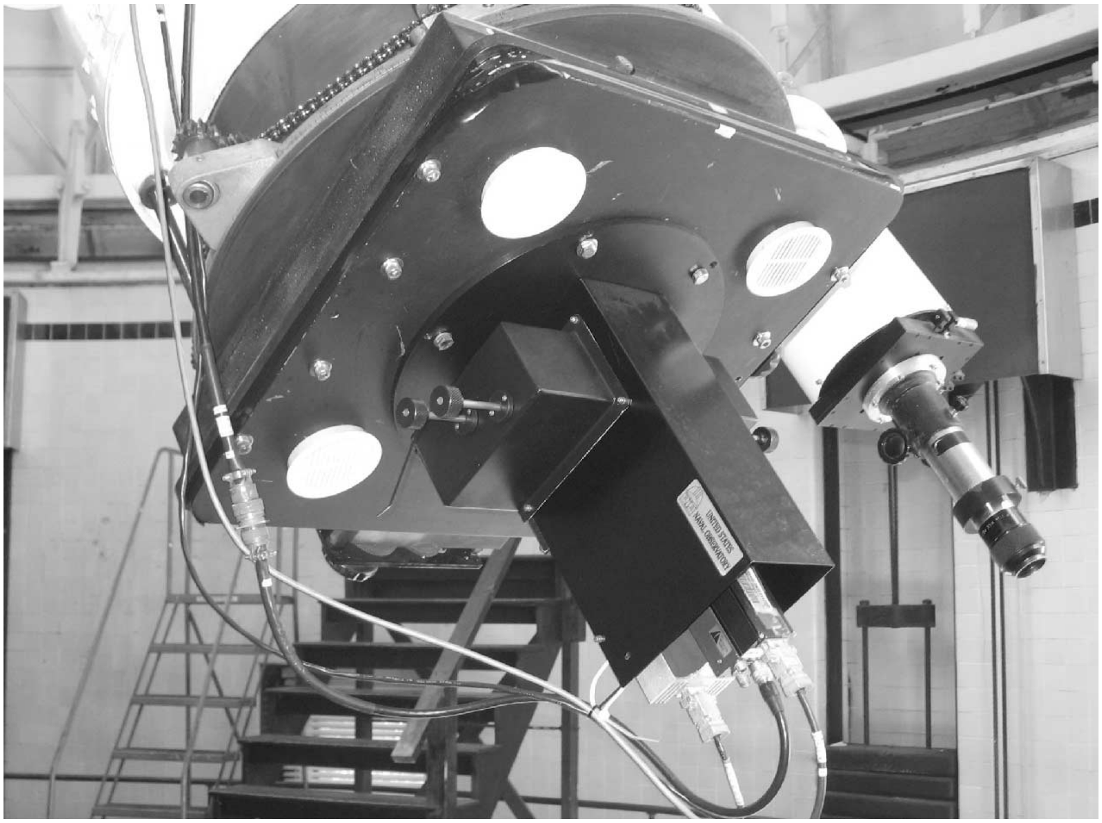

FIG. 1.—USNO secondary speckle camera mounted on the 26 inch telescope. The microscope objective and filter spindles are at left.

(see Douglass et al. 1997). Observation of a single star through this mask produces interference fringes that can then be used to determine spatial and angular calibration independent of any errors associated with using even "definitive" binaries.[1]

While this calibration method is suitable for the primary camera, changes in plate scale and the consequent coarseness of calibration peaks make it unsuitable for the secondary camera. However, the recent completion of the Catalog of Rectilinear Elements[2] (Hartkopf et al. 2006) presented another avenue for calibrating these wide systems. An assessment of *Hipparcos* and Tycho-2 proper motion by Kaplan & Snell (2001) using WDS pairs illustrated the high quality of these data and suggested that calibration using rectilinear fits to well-observed, likely optical double stars should be more reliable than one using dynamically interacting binary stars.

Calibration of measurements from the secondary camera was determined using wide pairs with well-defined rectilinear motion. An initial list of 272 observed pairs (316 observations) matched entries in Hartkopf et al. (2006), and predicted values of ρ and θ were calculated for dates corresponding to each observation. Weights were then derived for each observed (x, y) pair, based on quality assessments made at the time of initial data reduction. Weights for each corresponding calculated (ρ, θ) pair were based

[1] See http://ad.usno.navy.mil/wds/orb6/orb6c.html for more information.
[2] Available at http://ad.usno.navy.mil/wds/lin1.html.

TABLE 1
CAMERA COMPARISON

Parameter	Primary[a]	Secondary
Detector and intensifier	Sony XC-77 with Gen IIIc	Sony XC-77 with Gen II
Plate scale[b] (arcsec pixel^{-1})	0.0289	0.0900
Filter options	Strömgren *y*	Strömgren *y*
	USNO *g*[c]	Johnson *V*
	Johnson *V*	Clear[d]
Magnification options	10 times	3.5 times
	20 times	10 times
Limiting magnitude (*V*)	13th	11th

[a] Also includes Risley prisms to correct for dispersion. This factor is less significant on small telescopes with a low zenith distance.
[b] Plate scale is affected by camera focal length and microscope objective. This is the smallest pixel scale obtained of the specified camera.
[c] USNO *g* (green) is an intermediate interference filter for stars too faint for Strömgren *y* but too close for Johnson *V*. Central wavelength is 545 nm, and FWHM is 45 nm.
[d] Clear is filterless for very faint targets at low zenith distance.

TABLE 2

Pairs Measured for the First Time

α (J2000.0) (1)	δ (J2000.0) (2)	Discoverer Designation (3)	Est. Mag. Primary (4)	Est. Mag. Secondary (5)	Note (6)
00 29 27.07	+28 08 51.1	WSI 38 AB	10.3	. . .	1
19 45 33.52	+33 36 11.0	TKA 1 AE	8.5	11.7	2
20 18 05.63	+40 43 24.9	STF 2666 CD	11.0	11.1	3
20 58 14.88	+03 56 16.2	WSI 39 AD	10.6	12.6	4
20 58 13.57	+03 56 08.8	WSI 39 CD	11.6	12.6	

Notes.—(1) Serendipitously found while examining HAU 1. Magnitude of secondary unknown, but probably less than 11.5. The components of the HAU pair have been designated AC. (2) Tel'nyuk-Adamchuk (1966) actually observed the AD pair, but given its history in the catalog this new component is designated TKA 1 to avoid confusion, despite the fact that Tel'nyuk-Adamchuk never observed it. (3) With a smaller separation and magnitude difference, the CD pairing of this complex multiple system is easier to measure than either AC or AD. Work continues on both the closer pairs (T. A. ten Brummelaar et al. 2007, in preparation) and the entire μ Normae–type cluster, Collinder 419, of which these are two members (L. C. Roberts et al. 2007, in preparation). (4) Serendipitously found while examining BAR 13AC. The CD pairing is smaller and has a greater chance of dynamical interaction. The AD pairing is listed to provide the system's context relative to the primary of this multiple system. Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

on the formal errors derived for each solution term, as well as the number of observations entering into the linear solution. (This additional "number of observations" criterion was added in order to avoid giving too much weight to linear elements that have small formal errors due solely to very few observations being used in the fit; recall that two data points always yield a solution with zero error.)

The weight of a given data set—observed (x, y) and corresponding calculated (ρ, θ)—was defined as the product of those two weights. A total of 225 data sets received weights >0 and were used in the initial solution. Scale and angle zero points were calculated using a standard weighted linear least-squares calculation with these 225 data sets. Following this initial solution, seven outliers (>3 σ from the mean) were thrown out and the final solution calculated.

4. RESULTS

Table 2 presents coordinates and magnitude information from CDS[3] for those binaries which are resolved or measured for the first time. The two new systems were found as additional components to known pairs. Columns (1) and (2) give the coordinates of the primary of the pair. Column (3) gives the discoverer designation (where WSI = Washington Speckle Interferometry) number. Columns (4) and (5) give the estimated visual magnitudes of the primary and secondary of the pair described here. Column (6) gives notes indicating the circumstance of the discovery. The mean double-star positions (T, θ, and ρ) of these systems are given in subsequent tables.

Tables 3 and 4 include data obtained with the primary camera, while results from the secondary camera are given in Tables 5 and 6. These tables are described below.

4.1. *Primary Camera*

Table 3 presents the mean relative positions of the members of 178 systems with no published orbital elements. Columns (1) and (2) identify the system by providing the epoch J2000.0 coordinates and discovery designation. Columns (3)–(5) give the epoch of observation (expressed as a fractional Besselian year), the position angle (in degrees), and the separation (in arcseconds). Note that the position angle has not been corrected for precession and is thus based on the equinox for the epoch of observation. Objects whose measures are of lower quality are indicated by colons following the position angle and separation. These lower-quality observations may be due to one or more of the following: close separation, large Δm, one or both components being very faint, a large zenith

[3] Magnitude information is from the Aladin Sky Atlas, operated at CDS, Strasbourg, France.

TABLE 3

Speckle Interferometric Measurements of Double Stars

WDS Desig. α, δ (J2000.0) (1)	Discoverer Designation (2)	Epoch 2000+ (3)	θ (deg) (4)	ρ (arcsec) (5)	n (6)	Note (7)
01532+1526	BU 260	6.035	258.6	1.11	3	
02003+2436	COU 753	6.035	97.4	1.81	2	
02052−0058	BU 516	6.035	313.0	0.67	3	
02062+2507	STF 212	6.035	162.0	1.94	2	
02123+2357	STF 226	6.035	233.8	1.76	2	
02124+3018	STF 227	6.035	68.6	3.96	1	
02199+3047	A 960	6.035	314.1	1.09	1	
02211+2956	A 962	6.035	66.8	0.89	3	
02214+0853	BU 8	6.035	223.3	1.51	2	
02389−0135	HO 315	6.043	355.3	1.68	2	

Notes.—(C) Confirming observation. (1) Also known as BEM 15. (2) Earlier 2004 data not published (Mason et al. 2006b) due to larger than expected positional change. (3) Earlier 2005 data not published (Mason et al. 2006a) due to larger than expected positional change. (56–185) Number of years since last measure. Table 3 is published in its entirety in the electronic edition of the *Astronomical Journal*. A portion is shown here for guidance regarding its form and content.

TABLE 4

Speckle Interferometric Measurements and Residuals of Systems with Orbits or Linear Elements

WDS Desig. α, δ (J2000.0) (1)	Discoverer Designation (2)	Epoch 2000+ (3)	θ (deg) (4)	ρ (arcsec) (5)	n (6)	$O-C$ (deg) (7)	$O-C$ (arcsec) (8)	Reference (9)	Notes (10)
02020+0246	STF 202 AB	6.035	269.6	1.81	2	2.2	0.02	Scardia (1983)	*
02407+2637	STT 43	6.043	349.9	0.69	2	1.4	0.00	Scardia et al. (2001a)	
03368+0035	STF 422	6.035	271.8	6.66	1	1.0	−0.02	Hopmann (1964)	*
05005+0506	STT 93	6.043	245.1	1.41	2	0.7	−0.03	Seymour & Mason (1999)	*
05364+2200	STF 742	6.104	273.3	4.00	2	−1.1	−0.11	Hopmann (1973)	*
05371+2655	STF 749 AB	6.112	321.7	1.15	2	−0.3	0.00	Scardia et al. (2005)	
06462+5927	STF 948 AB	6.106	71.4	1.78	2	1.2	−0.08	Mason et al. (2006a)	
08531+5457	A 1584	6.278	81.0	0.59	2	−0.9	−0.03	Heintz (1991)	
08554+7048	STF 1280 AB	6.278	347.1	1.95	1	0.0	0.07	Heintz (1997)	*
09210+3811	STF 1338 AB	6.279	296.3	1.05	2	−1.5	0.04	Scardia et al. (2002)	
09245+1808	A 2477	6.322	356.6	0.43	1	1.7	−0.04	Mason & Hartkopf (1998)	*
09525−0806	AC 5 AB	6.320	50.3	0.59	1	−3.3	−0.01	Heintz (1982)	
10131+2725	STT 213	6.322	122.2	1.04	1	3.4	0.02	Heintz (1962)	
10163+1744	STT 215	6.278	179.6	1.45	1	−0.2	−0.06	Zaera (1984)	
10269+1713	STT 217	6.320	145.8	0.68	1	−1.9	−0.03	Heintz (1975)	
10480+4107	STT 229	6.295	263.5	0.66	1	−0.9	−0.02	Alzner (1998)	
11182+3132	STF 1523 AB	6.318	238.5	1.66	7	1.3	−0.04	Mason et al. (1995)	2, *
		6.394	237.6	1.68	4	1.0	−0.01	Mason et al. (1995)	2, *
11308+4117	STT 234	6.323	167.1	0.46	1	0.0	−0.04	Docobo & Ling (2001)	
12095−1151	STF 1604 AB	6.298	88.9	9.22	1	0.3	−0.10	Hartkopf et al. (2006)	
12095−1151	STF 1604 AC	6.298	23.4	10.19	1	0.3	−0.07	Hartkopf et al. (2006)	
12108+3953	STF 1606	6.320	163.1	0.42	1	1.9	0.00	Mason et al. (1999)	
12244+2535	STF 1639 AB	6.345	324.4	1.74	3	0.4	−0.02	Olevic & Popovic (2000)	*
12272+2701	STF 1643	6.295	8.7	2.51	1	2.8	−0.18	Mason et al. (2004b)	
						2.9	−0.17	Olevic & Cvetkovic (2003)	
12306+0943	STF 1647	6.347	246.0	1.30	2	−3.0	0.03	Hopmann (1970)	*
12417−0127	STF 1670 AB	6.330	84.6	0.46	3	0.1	−0.02	Scardia et al. (2006)	2
		6.394	82.1	0.49	2	0.7	0.00	Scardia et al. (2006)	2
13100+1732	STF 1728 AB	6.320	11.8	0.53	2	−0.6	0.02	Mason et al. (2006a)	*
13235+2914	HO 260	6.391	85.5	1.49	1	2.2	−0.08	Mason et al. (2004b)	
13328+1649	VYS 6	6.391	47.3	2.85	1	−0.9	−0.06	Heintz (1990)	
13347−1313	BU 932 AB	6.347	57.1	0.37	1	−3.0	−0.03	Starikova (1980)	
13375+3618	STF 1768 AB	6.320	98.4	1.80	2	0.9	0.05	Söderhjelm (1999)	
13379+4808	ES 608 AB	5.403	322.1	1.75	1	−0.2	−0.11	Seymour et al. (2002)	1
		6.298	324.9	1.78	2	1.7	−0.07	Seymour et al. (2002)	
13461+0507	STF 1781	6.321	189.7	0.84	2	7.6	−0.01	Heintz (1986a)	
13491+2659	STF 1785	6.295	178.1	3.18	2	0.0	−0.01	Heintz (1988)	
13550−0804	STF 1788 AB	5.356	98.7	3.64	1	0.1	0.10	Hopmann (1970)	1, *
		6.347	99.1	3.67	2	0.3	0.13	Hopmann (1970)	*
13577+5200	A 1614	6.298	122.8	1.34	2	−1.4	−0.09	Heintz (2001)	
14024+4620	SWI 1	6.296	24.6	3.65	1	−0.2	0.00	Seymour et al. (2002)	
14131+5520	STF 1820	6.296	119.5	2.67	1	−0.1	0.07	Kiyaeva et al. (1998)	*
14153+0308	STF 1819	6.320	186.9	0.86	1	−0.1	−0.02	Houser (1987)	
14203+4830	STF 1834	6.296	101.7	1.54	1	−1.7	0.02	Seymour & Mason (2000b)	
14369+4813	A 347	6.296	244.6	0.57	1	−3.4	−0.01	Docobo & Ling (2004)	
14411+1344	STF 1865 AB	6.320	296.7	0.63	1	−0.3	−0.03	Wierzbinski (1956)	
14428+0635	A 1109 AB	6.391	83.5	1.66	2	−3.1	−0.02	Mason et al. (2006a)	
14455+4223	STT 285 AB	6.320	94.3	0.47	1	−0.6	−0.01	Couteau (1973)	
14514+1906	STF 1888 AB	6.320	312.5	6.42	1	0.4	0.12	Söderhjelm (1999)	
14515+4456	STT 287	6.301	357.8	0.76	1	1.9	−0.06	Heintz (1997)	
14534+1542	STT 288	6.356	163.5	1.07	2	0.4	−0.05	Heintz (1998)	
15038+4739	STF 1909	6.320	58.1	1.90	2	1.1	−0.01	Söderhjelm (1999)	
15183+2650	STF 1932 Aa-B	6.416	263.1	1.61	2	1.0	−0.02	Muller (1952)	
15232+3017	STF 1937 AB	6.396	124.6	0.52	2	−1.8	0.01	Mason et al. (2006a)	*
15245+3723	STF 1938 BC	6.320	7.1	2.27	1	0.6	0.02	Söderhjelm (1999)	
15348+1032	STF 1954 AB	6.356	173.1	3.99	1	0.1	0.00	Mason et al. (2004b)	
15360+3948	STT 298 AB	6.320	173.9	0.92	1	0.9	−0.02	Söderhjelm (1999)	*
16137+4638	A 1642	6.320	184.2	0.69	1	1.2	−0.02	Hartkopf & Mason (2001)	
16147+3352	STF 2032 AB	6.320	237.6	7.05	1	0.7	−0.08	Scardia (1979)	*
16160+0721	STF 2026	6.328	18.7	3.33	1	0.1	−0.03	Heintz (1963)	*
16289+1825	STF 2052 AB	6.394	121.8	2.17	1	0.2	0.04	Söderhjelm (1999)	
16309+0159	STF 2055 AB	6.397	34.2	1.40	2	0.0	−0.06	Heintz & Strom (1993)	
16413+3136	STF 2084	6.397	209.1	0.99	2	−1.7	−0.05	Söderhjelm (1999)	*

TABLE 4—*Continued*

WDS Desig. α, δ (J2000.0) (1)	Discoverer Designation (2)	Epoch 2000+ (3)	θ (deg) (4)	ρ (arcsec) (5)	n (6)	$O-C$ (deg) (7)	$O-C$ (arcsec) (8)	Reference (9)	Notes (10)
16511+0924	STF 2106	6.394	174.8	0.70	3	1.6	−0.03	Scardia et al. (2001b)	
16518+2840	STF 2107 AB	6.329	100.0	1.47	1	−0.8	0.09	Scardia et al. (2003)	
17053+5428	STF 2130 AB	6.328	12.3	2.30	1	2.0	0.00	Heintz (1981b)	*
17146+1423	STF 2140 Aa-B	5.663	104.2	4.81	4	0.2	0.16	Baize (1978)	1
		6.389	103.1	4.78	1	−0.8	0.13	Baize (1978)	
17386+5546	STF 2199	6.328	57.8	1.96	1	2.7	0.04	Popovic & Pavlovic (1995)	
18097+5024	HU 674	6.389	220.5	0.65	3	4.4	0.01	Seymour et al. (2002)	
18250+2724	STF 2315 AB	6.394	121.3	0.63	1	0.7	−0.01	Mason et al. (2004a)	
18355+2336	STT 359	6.389	5.9	0.72	2	1.0	0.00	Symms (1964)	
18443+3940	STF 2382 AB	6.394	348.9	2.35	1	0.3	−0.06	Mason et al. (2004a)	
						0.2	−0.03	Novakovic & Todorovic (2005)	
18443+3940	STF 2383 Cc-D	6.394	80.5	2.38	1	0.8	0.02	Docobo & Costa (1984)	*
18462+6412	HU 937	6.394	331.5	0.97	3	0.5	0.01	Brendley & Mason (2006)	
19121+4951	STF 2486 AB	5.720	205.7	7.30	1	0.0	−0.11	Hale (1994)	1, *
		6.389	205.6	7.28	2	0.1	−0.12	Hale (1994)	*
19266+2719	STF 2525	6.394	289.6	2.06	1	−0.6	−0.02	Heintz (1984b)	*
19456+3337	STF 2576 AB	6.389	160.7	2.85	1	−0.2	0.02	Söderhjelm (1999)	

Notes.—An asterisk indicates a system used in characterizing errors. (1) This measure was inconsistent with previous measures and thus not included in Mason et al. (2006a). However, available data are deemed insufficient for a new orbital calculation at this time. (2) This system was expected to show significant motion over the calendar year, and thus multiple observations have been obtained. Table 4 is also available in machine-readable form in the electronic edition of the *Astronomical Journal*.

distance, and poor seeing or transparency. They are included primarily due to either the confirming nature of the observation or the number of years since the last measured position. Column (6) indicates the number of observations contained in the mean, and column (7) flags any notes. While column (6) reflects the number of measurements, each measurement represents the combination of over 2000 short-exposure images, from which a single measurement is obtained in autocorrelation space.

The most common note indicators are "C," indicating a confirming observation, or a number (N), indicating the number of years since the system was last measured. This is only given for systems with $N \geq 50$ yr. Fifteen systems are confirmed here. Since priority is given to both unconfirmed systems and systems not observed recently, the time since last observation can be surprisingly large; for the systems in Table 3 the average time since last observation is 16 yr (85 yr for those with a colon, i.e., of reduced accuracy). Eighteen systems have not been observed in the last 50 years or more, and four have not been observed in 100 years or more. The maximum such time span was 185 yr, as HJ 729 was initially resolved by J. Herschel in 1820 (Herschel 1829). The long delay in confirming these historic pairs was simply due to poor coordinates; most had only arcminute-precise published coordinates, precessed without proper-motion correction from the original coarse α and δ. The 178 measurements in Table 3 (i.e., systems without orbits), plus the two linear solutions of Table 3, have a mean separation of 3.91″.

Table 4 presents the mean relative positions for 76 binary star systems with published orbital determinations, as well as two pairs with linear solutions. The first six columns are identical to the corresponding columns of Table 3. Columns (7) and (8) give $O-C$ orbit residuals (in θ and ρ) to the orbit referenced in column (9). Notes are designated in column (10). The objects in Table 4 tend to be more frequently observed, closer pairs than those in Table 3, with a mean separation of 1.98″ and a mean time interval since last observation of only 1.5 yr. Considering those binaries with calibration orbits (indicated by an asterisk

TABLE 5
ICCD Measurements of Double Stars

WDS Desig. α, δ (J2000.0) (1)	Discoverer Designation (2)	Epoch 2000+ (3)	θ (deg) (4)	ρ (arcsec) (5)	n (6)	Notes (7)
00016+1658	J 215	6.941	35.5	3.15	1	53
00026+6606	STF 3053	6.586	69.9	15.03	1	
00068−2106	RSS 41	6.927	344.2	9.70	1	C, P
00087+5006	ES 443	6.971	32.4:	5.27:	2	81
00094−2759	BU 391	6.940	259.8	1.31	3	
00118+3608	BU 1340	6.941	228.0	3.60	1	60
00141+1207	A 1802	6.941	146.9:	1.73:	1	57
00150+0849	STF 12	6.605	147.9	11.30	1	
00159+5233	ES 865 AC	6.924	69.0	12.13	3	
00183+5531	A 906	6.971	310.6	2.89	1	60

Notes.—(C) Confirming observation. (P) Given the proper motion and time since the last observation, this pair is identified as a CPM binary. (1) Also see Table 1. (2) Hyperbolic orbit to this pair given in Hopmann (1967). (50–178) Number of years since last measure. Table 5 is published in its entirety in the electronic edition of the *Astronomical Journal*. A portion is shown here for guidance regarding its form and content.

TABLE 6

ICCD Measurements and Residuals of Systems with Orbits or Linear Elements

WDS Desig. α, δ (J2000.0) (1)	Discoverer Designation (2)	Epoch 2000+ (3)	θ (deg) (4)	ρ (arcsec) (5)	n (6)	$O-C$ (deg) (7)	$O-C$ (arcsec) (8)	Reference (9)	Notes (10)
00014+3937	HLD 60	6.900	169.9	1.25	2	−0.9	0.02	Heintz (1963)	
00032+4508	HJ 1927	6.605	73.2	10.10	2	0.4	−0.04	Hartkopf et al. (2006)	*
00047+3416	STF 3056 AB-C	6.941	1.6	26.14	1	−1.0	0.44	Hartkopf et al. (2006)	*
00057+4549	STT 547	6.614	184.6	6.06	3	−0.3	0.11	Popovic & Pavlovic (1996)	
						0.0	0.01	Kiyaeva et al. (2001)	
00063+5826	STF 3062	6.933	341.9	1.49	4	0.7	−0.04	Söderhjelm (1999)	
00100−2829	HDS 22	6.952	223.0	8.24	1	−1.8	−0.06	Hartkopf et al. (2006)	
00159+5233	ES 865 AB	6.936	100.4	3.68	4	−0.2	−0.07	Hartkopf et al. (2006)	*
00175+0019	STF 23	6.941	219.9	9.42	1	1.1	0.19	Hartkopf et al. (2006)	*
00187+2545	HJ 1015	6.605	291.2	5.44	1	0.8	0.36	Hartkopf et al. (2006)	*

Notes.—An asterisk indicates a system used in calibration. Table 6 is published in its entirety in the electronic edition of the *Astronomical Journal*. A portion is shown here for guidance regarding its form and content.

in col. [10]), the mean of the absolute value $O-C$ in position angle and separation is 1.1° and 5.6%. However, as demonstrated in Mason et al. (2006a), even calibration orbits are often not sufficiently characterized for error estimation; even "grade one" orbits (which exhibit smaller values of 1.2° and 2.2%) are insufficient. Given the improvements seen in calibration binaries, it is likely that they are adequate for gross calibration but are not suitable for precise differential astrometry or true error identification.

While many objects have more than one observation generating a mean position, two objects have motion which is rapid enough that listing multiple mean positions was deemed appropriate. In two other cases, more than one orbit is provided in the Sixth Catalog of Orbits of Visual Binary Stars,[4] and the preferred orbit is not certain. Residuals are provided for both orbits.

4.2. *Secondary Camera*

Statistics for the secondary camera are generally reflective of the longer observing period and wider separation regime: 68 systems are confirmed here with a mean time since last observation of 20 yr (72 yr for those measures of reduced accuracy). One hundred thirty-three systems have not been observed in the last 50 years or more, and 29 have not been observed in 100 years or more, with a maximum of 178 yr. HJ 5523 was first resolved by J. Herschel in 1827 (Herschel 1870). The mean separation for the measurements presented in Tables 5 and 6 is 16.97″.

A high proper motion rate, coupled with a long period of neglect, allows us to characterize some pairs as common proper motion (CPM) systems. These are so wide that negligible orbital motion would be expected; therefore, recovering them approximately at the same location allows the CPM determination to be made. Sixteen systems, identified with a "P," are noted in Table 5.

Two new pairs were serendipitously discovered during these observations. While searching for 00296+2807 = HAU 1, a closer pair was noted. The component designation for the known HAU 1 pair has been changed to AC, while the new pair, identified as WSI 38, is AB. Similarly, in an examination of 20582+0356 = BAR 13, a companion was resolved relative to C. This new D component, designated WSI 39, is measured relative to both A and C in Table 5.

[4] Available at http://ad.usno.navy.mil/wds/orb6.html.

TABLE 7

Binaries Not Found

		Observation			Published Magnitude		
Coordinate α, δ (J2000.0)	Discoverer Designation	Date	Position Angle (θ)	Separation (ρ)	Primary	Secondary	Notes
12497+0111..........................	OSO 48 AC	1994	53	8.5	8.1	10.7	
14137+1734	COU 60	1965	281	6.3	10.1	11.8	1
14581+3556	TDS 9353	1991	78	2.4	10.9	12.3	
18162+2211	TDT 766	1991	213	2.4	10.6	12.1	
20172+0504	BAL 2965	1910	134	18.6	9.6	10.2	
20492+3917	ALI 952	1929	53	6.9	8.3	9.2	2
22003+4423	SMA 156	1909	226	10.8	10.4	10.6	
22066+4156	DOO 90	1907	220	4.7	9.5	9.7	
22113+4010	GLP 20 AB-C	1894	354	32.2	8.6	10.1	3
22349+3702	ES 2532	1931	293	6.1	9.7	10.2	
22410+0052	HJ 3132 AC	1922	79	22.4	10.5	11.0	
23096+0045	GAU 20 AB	1920	19	9.3	10.4	11.2	
23108+4531	HJ 1853	1905	191	33.2	7.0	7.7	
23207+0356	BAL 2578	1910	271	17.9	10.6	10.7	

Notes.—(1) The DM cross reference given in Couteau (1966) does not match the coordinates in the paper, but the pair is not found at either location. (2) *Hipparcos* "suspected nonsingle" (Perryman et al. 1997, field H61), possibly due to input catalog listing, but no indication of duplicity here. (3) Three measures from 1874 to 1894 (Wilson & Seabroke 1875, 1877; Glasenapp 1895) and nothing since. Since 1894 the AB pair has been measured 67 times with no accompanying measure of the wide pair.

Another pair, 19456+3337 = TKA 1, while cataloged before, is measured here for the first time. Tel'nyuk-Adamchuk (1966) actually observed the AD pair of this multiple system, but, due to the high proper motion of A and the long period of time since the previous AD measure, his observation was mistakenly assigned to a new component, called "E." His measurement has now been placed with AD; however, a new component, at about the same distance as that measured by Tel'nyuk-Adamchuk, appears to have a proper motion similar to that of A and B. The TKA 1 designation has been maintained in order to avoid further confusion, despite the fact that Tel'nyuk-Adamchuk never actually observed it.

Finally, the bright multiple 20181+4044 = STF 2666, found at the heart of the μ Normae–type cluster Collinder 419 (L. C. Roberts et al. 2007, in preparation), has many components. While not as dynamically interesting as the closer pairs (T. A. ten Brummelaar et al. 2007, in preparation), components C and D are closer to each other than to A, and they are also quite similar in magnitude. This pairing is, therefore, more likely to have higher relative precision due to its greater applicability for long-focus work.

Table 6 presents the mean relative positions for 71 binary star systems with published orbital determinations, as well as 270 pairs with linear solutions. The first six columns are identical to the corresponding columns of Tables 3–5. Columns (7) and (8) give $O-C$ residuals (in θ and ρ) of the orbit referenced in column (9) or the linear solution source. Notes are designated in column (10). Observations used in the calibration of these data are flagged with an asterisk.

4.3. *Double Stars Not Found*

Table 7 presents 14 systems which were observed with either the primary or secondary camera but not detected. Three of these are systems with high proper motion and long periods of neglect, as described in § 4.2. Possible reasons for no detection include orbital or differential proper motion making the binary too close or too wide to resolve at the epoch of observation, a larger than expected Δm, incorrect pointing, and misprints and/or errors in the original reporting paper. It is hoped that reporting these will encourage other double-star astronomers to either provide corrections to the USNO observations or verify the lack of detection.

The continued instrument maintenance by the USNO instrument shop, John Evans, Tie Siemers, and David Smith, makes the operation of a telescope of this vintage a true delight. Thanks also to Ted Rafferty (USNO, retired) for his assistance with equipment upgrades and maintenance and the foresight to initiate the secondary camera project.

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